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Name: Carolyn Bova	
Signature: <u>Carolyn Bova</u>	

## CONTROL CIRCUIT AND METHOD FOR CRYSTAL OSCILLATOR CIRCUITRY

### BACKGROUND OF THE INVENTION

#### Technical Field of the Invention

The present invention relates to oscillator circuitry, and particularly to circuitry for controlling current  
5 dissipated by crystal oscillator circuits.

#### Description of the Related Art

Crystal oscillators have been used in the electronics industry for decades for providing a clock or other signal  
10 having a fixed, predetermined frequency. For certain applications, some existing crystal oscillator circuits operate at relatively low voltage and low current levels. However, these low voltage, low current oscillator circuits take an appreciably long time to start up and stabilize.

Oscillator circuits having a relatively prolonged time to start-up and stabilize adversely affect normal system operation as well as testing of the circuitry associated with the oscillator circuits.

5           At least one existing oscillator circuit design allows for higher current dissipation by the oscillator when initially started, and thereafter switches the oscillator current to a lower current level. This existing oscillator circuit utilizes an amplitude detector to detect current  
10   level consumed by the oscillator circuit and to provide feedback to the current source providing current to the oscillator circuit based upon the current detected. A problem with this existing oscillator circuit, however, is that it results in a rather complex circuit design. What is  
15   needed, then, is an oscillator circuit that quickly starts and stabilizes with little overhead.

#### **SUMMARY OF THE INVENTION**

Embodiments of the present invention overcome the above-  
20   discussed shortcomings with existing oscillator circuits and satisfy a significant need for an oscillator circuit that quickly and stably commences oscillating. According to an exemplary embodiment of the present invention, oscillator

circuitry may include a crystal oscillator circuit adapted to oscillate at approximately a predetermined frequency, and a control circuit that controls the amount of current dissipated by the crystal oscillator circuit. The control  
5 circuit may include a timer circuit for counting a predetermined period of time following the occurrence of an event, such as completion of a power-up sequence. Upon completion of the predetermined period of time, the timer circuit controls a current source providing current to the  
10 crystal oscillator circuit to source a current level thereto that is less than the current level initially sourced to the crystal oscillator circuit. In this way, the crystal oscillator circuit is capable of quickly and stably commencing oscillating with little overhead, while  
15 dissipating relatively little power.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

A more complete understanding of the system and method of the present invention may be obtained by reference to the  
20 following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

Figure 1 is a block diagram of oscillator circuitry according to an exemplary embodiment of the present invention;

Figure 2 is a circuit diagram of the oscillator  
5 circuitry of Figure 1;

Figure 3 is a circuit diagram of a portion of the oscillator circuitry of Figure 1, according to another exemplary embodiment of the present invention; and

Figure 4 is a flow chart illustrating an operation of  
10 the oscillator circuitry of Figure 1.

#### **DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS**

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in  
15 which exemplary embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, the embodiments are provided so that this disclosure will be thorough and  
20 complete, and will fully convey the scope of the invention to those skilled in the art.

Referring to Figure 1, there is shown oscillator circuitry 1 that relatively quickly begins oscillating in a

stable manner, according to an exemplary embodiment of the present invention. Oscillator circuitry 1 is adapted to control current dissipation so that oscillation initially occurs at a first current level followed by oscillation at  
5 a second current level that is less than the first current level. Oscillator circuitry 1 may be part of a system 100 that may further include logic circuitry 50 which receives the output of oscillator circuitry 1 and is adapted to perform one or more predetermined operations from utilization  
10 of the output of oscillator circuitry 1. For example, logic circuitry 50 may perform one or more synchronous operations by using the output of oscillator circuitry 1 as a clock signal.

Specifically, oscillator circuitry 1 may include a  
15 crystal oscillator circuit 2 adapted to generate an output signal that oscillates at approximately a predetermined frequency. Crystal oscillator circuit 2 may have a conventional implementation for a crystal oscillator, and include a crystal 3, a logic inverter 4 connected across the  
20 terminals of crystal 2, and a pair of capacitors 5 (see Figure 2). Each capacitor 5 may be coupled between a distinct terminal of crystal 2 and a voltage reference, such

as ground. The operation of the above-described conventional crystal oscillator circuit 2 is known in the art and will not be described in detail for reasons of simplicity.

It is understood that crystal oscillator circuit 2 may have different circuit implementations. It is further understood that crystal oscillator circuit 2 may include or be otherwise associated with additional circuitry not shown in Figure 1, such as a frequency divider circuit that generates a signal having a frequency that is a fraction of the frequency at which crystal oscillator circuit 2 oscillates. Alternatively, oscillator circuitry 1 may include other oscillator circuits and/or components that do not utilize a crystal.

Oscillator circuitry 1 may further include a current source 7 that provides current to or sinks current from crystal oscillator circuit 2. Current source 7 may have any of a plurality of implementations, as described below. Current source 7 may include a control input 7a utilized to control the amount of current sourced by or sunk from current source 7.

Oscillator circuitry 1 may further include a control circuit 8 that controls current source 7 and thereby controls the current that is sourced to or sunk from crystal

oscillator circuit 2. According to an exemplary embodiment of the present invention, control circuit 8 may receive a control input 8a having a value indicative of the occurrence of an event, and an output 8b coupled to the control input 5 7a of current source 7 for use in controlling the amount of current dissipated by crystal oscillator circuit 2. Control circuit 8 may include timing circuitry for causing current source 7 to switch from a higher current level to a lower current level a period of time following the occurrence of 10 an event.

With reference to Figure 2, control circuit 8 may include a timer circuit adapted to count a predetermined number of cycles appearing on a signal applied to a clock input 8c of control circuit 8. In an exemplary embodiment 15 of the present invention, the timer circuit may include at least two flip-flop circuits 10 connected in cascade relation so that an output of a first flip-flop 10a is coupled to the data input of a second flip-flop 10b. The output 8b of control circuit 8 may be coupled to an output of flip-flop 20 10b. The clock input of each flip-flop 10 may be coupled to the clock input 8c of control circuit 8. In this way, the output of flip-flop 10b may follow the logic value provided

- to the data input of flip-flop 10a, delayed by two cycles of the clock input 8c.

A data input of flip-flop circuit 10a may be coupled to a voltage potential representative of a predetermined logic level, such as power supply Vcc (representative of a logic high value). Flip-flop circuits 10 may also include a control input for placing the flip-flops 10 in one or more predetermined states. In the exemplary embodiment of the present invention shown in Figure 2, the control input of flip-flop circuits 10 may be a reset input to selectively reset flip-flops 10. Alternatively, the control input of flip-flops 10 may set flip-flops 10 to one or more other states, such as a set state. In this alternative embodiment in which flip-flops 10 have set inputs, the data input of flip-flop 10a may be coupled to a voltage level representative of a logic low value, such as ground.

As mentioned above, control circuit 8 may control current source 7 to selectively change current provided to or sunk from crystal oscillator circuit 2 from a first current level to a second current level, following the occurrence of an event. In particular, the control input 8a of control circuit 8 may receive a signal having a value indicative of the occurrence of the event. The event may be,



for example, the completion of a start-up sequence by the system which utilizes the output of crystal oscillator circuit 2. In this regard, the control input 8a of control circuit 8 may be driven by power-on-reset circuitry of the system. Alternatively, the event may be the system switching from one power source to another, such as switching to a battery back-up source. In this way, the control input 8a of control circuit 8 may be driven by a signal indicating the system being in the battery back-up mode of operation. It is understood that the event, and thus the circuit that drives the control input 8a of control circuit 8, may be other events as well.

The signal applied to the clock input 8c of control circuit 8 may have a frequency that allows for a desired predetermined period of time to elapse. Of course, the frequency of the signal appearing on clock input 8c and the number of cascaded flip-flops 10 in the timer circuit may be selected to provide the predetermined time period desired. In an exemplary embodiment of the present invention, the clock input 8c of control circuit 8 may be a divided-down version of the output of crystal oscillator 2. A frequency divider 11, may receive as a (clock) input the output of crystal oscillator 2 and generate an output signal having a

divided-down frequency thereof that is applied to the clock input 8c of control circuit 8. By way of one example, the signal appearing at the clock input 8c of control circuit 8 may be approximately 1Hz, which thereby results in the timer of control circuit 8 having a delay of approximately two  
5 seconds (for a two flip-flop timer).

Figure 2 also shows one possible implementation of current source 7. Current source 7 may be implemented as a current mirror circuit including a first current leg 13 and  
10 a second current leg 14 adapted to source current to crystal oscillator circuit 2. First current leg 13 may include one or more series-connected resistive elements 15 and a transistor 16 coupled across at least one of the resistive elements 15. The transistor 16 may include a control (gate)  
15 terminal coupled to the output 8b of control circuit 8 via a logic inverter. Activation of transistor 16 by control circuit 8 shorts the voltage across the corresponding resistive element 15 so as to change (increase) the current level of current leg 13, which thereby proportionally changes  
20 (increases) the current in current leg 14. In this way, control circuit 8 is capable of setting the current level of crystal oscillator circuit 2 to any of at least two current settings.

It is understood that current source 7 may be implemented in other ways. Figure 3 shows another possible implementation of current source 7 and its relationship with control circuit 8 and crystal oscillator circuit 2. In this  
5 exemplary embodiment, current source 7 is implemented as a number of series-connected resistive elements 18 coupled between a voltage source, such as Vcc, and crystal oscillator circuit 2. A transistor 19 may be coupled across at least one of the resistive elements 18 and include a control  
10 terminal coupled to the output 8b of control circuit 8. Activation of transistor 19 shorts the voltage across the corresponding resistive element 18 so as to change (increase) the current level to crystal oscillator circuit 2. In this way, control circuit 8 is capable of setting the current  
15 level of crystal oscillator circuit 2 to any of two current settings.

It is understood that the current source may be implemented in a number of ways that are different from the implementations shown in Figures 2 and 3.

20 The operation of oscillator circuitry 1 will be described with reference to Figure 4. The exemplary embodiment of oscillator circuitry 1 whose operation will be described is the one which is responsive to a power-up

sequence. Initially, the power-up sequence is started. The power-up sequence may include ramping up the supply voltage Vcc from a ground potential to the desired power supply voltage level. during this time, control input 8a, which may  
5 be driven by power-on-reset circuitry of the system in which oscillator circuitry 1 is located, may be placed in an inactive state so that flip-flops 10 are reset. Flip-flops 10 being reset causes output 8b to be in the logic low state which turns on transistor 16. Transistor 16 being activated  
10 results in a relatively high current level flow through the first current leg 13 in current source 7, which thereupon causes a relatively high current level flow through current leg 14. As a result, a relatively high current level is sourced to crystal oscillator circuit 2. During this time,  
15 frequency divider 11 generates an output signal having a frequency that is divided-down from the frequency at which crystal oscillator circuit 2 oscillates.

Upon completion of the power-up sequence, control input 8a is driven to the active state so that flip-flops 10 are  
20 capable of storing data. A logic high value is stored in flip-flop 10a following a triggering edge of the signal generated by frequency divider 11. Logic high values are stored in both flip-flops 10 following the second triggering

edge of the signal generated by frequency divider 11 (i.e., the occurrence of the predetermined period of time following the completion of the power-up sequence). At that time, the output 8b of control circuit 8 changes from a logic low state  
5 to a logic high state, which causes transistor 16 to turn off. Transistor 16 turning off causes the current level in current leg 13 of current source 7 to lower, which thereupon causes the current level in current leg 14 to lower proportionally. Crystal oscillator circuit 2 oscillates at  
10 the lower current level as a result.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would  
15 be obvious to one skilled in the art are intended to be included within the scope of the following claims.